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THE STATIONARITY STUDY OF MONTHLY NUMBER OF EARTHQUAKES AND ENERGY RELEASED IN TAIWAN

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Abstract

The seismic properties, longitude, latitude, depth, magnitude, and intensity, etc. of each earthquake are recorded in the public archive of the Central Weather Bureau (CWB) of Taiwan. Two types of earthquakes, labelled and unlabeled, are stored in the data base. The labelled ones have Richter magnitude scale larger than 4.0, and influence several cities and counties. On the other hand, the unlabeled ones only affect in the locality. Twenty-three years and five months - January 1995 to May 2018 are collected from CWB's archive in this study.

The purpose of this paper is to check the stationary of the monthly total (labelled plus unlabeled) and labelled number of earthquakes as well as their energy released time series in the 20 municipal cities and counties in Taiwan to avoid the spurious condition when performing regression analysis. The augmented Dickey-Fuller (ADF) method is used to check the stationary of monthly number of earthquakes and their energy released time series. After a careful hypothesis test at 5% significance, the following time series are stationary. They are: monthly total number of earthquakes; monthly labelled number of earthquakes; energy released by the monthly total number of earthquakes and energy released by the monthly labelled earthquakes. However, the time series of yearly number of earthquakes is no stationary. The stationary of the yearly labelled number of earthquakes is indecisive due to the lack of enough data. A positive relationship between earthquake numbers and energy released has been obtained. The energy is calculated in terms of the code-named Little Boy atomic bomb, which was dropped in Hiroshima, Japan. The coefficient of determination, which means the percentage of the independent variable can be explained through knowledge of the variability in the independent variable, which is as high as 25.57% for the energy released and labelled monthly number of earthquakes.

Key Words: CWB Archive, Little Boy, Stationary, Spurious

Introduction

In this study, the number of earthquakes of each month and every city is collected from the public archive of the Central Weather Bureau (CWB) in Taiwan. This precious data base records all earthquakes which occurred in Taiwan from January 1995 up to now. Each earthquake's location, depth, magnitude, and intensity of the nearby cities and counties are well recorded. Two types of earthquake are in the CWB's file, labelled and unlabeled. The labelled ones are those larger than 4.0 Richter magnitude scale and affect several cities and counties, and unlabeled ones usually influence only in the locality. The labelled earthquake always renews from number one at the beginning of each year. Not until May 2000 did the CWB begin to put unlabeled earthquakes in its archive. The reason behind it may be due to on September 21, 1999 a catastrophic 7.3 Richter magnitude scale earthquake occurred in Manitou, and caused 2,415 deaths and 11,305 injured [4]. To record those unlabeled earthquakes will make data more complete and can trace the aftershocks of stronger earthquakes.

The energy issued from an earthquake is huge. The energy calculation is based on the equation given by Gutenberg and Richter [2]. It has the form $\log E = 11.8 + 1.5 M_s$, where E is energy in ergs and M_s is the surface wave magnitude [2,3]. To make manipulation of data easier, the energy released from each earthquake is assembled month by month and their energy is "normalized" by the energy generated by the atomic bomb with code-named Little Boy, which was dropped in Hiroshima, Japan. When the Little Boy was detonated, it produced 63 TJ (6.3E+20 ergs) of energy [5].

A variable being stationary means that one is not explosive, nor trending, and nor wandering aimlessly without returning to its mean [6,7]. If two no stationary time-series perform regression analysis, the result will be spurious [7], i.e. not true. Therefore, before embarking regression analysis, the stationary of a time series should be examined first. In this study, the number of earthquakes and energy equivalent atomic bomb numbers are arranged monthly from January 1995 to May 2018 (281 months). If the relationship between energy released and the number of earthquakes per month can be established, then as long as the number of earthquakes of a month is known, the energy released from these earthquakes can be obtained from the regression equation. However, the stationary of a time-series should be checked before starting regression analysis. The augmented Dickey-Fuller (ADF) is one of the most popular unit root tests [7], and in this study, the ADF is used to check the stationary of time series for monthly number of earthquake and energy equivalent to the number of atomic bombs. The famous program State is used to evaluate the stationary of a time series, and then double checked by thee views. The graphs in this paper are plotted by Minitab software.

Earthquake numbers per year in Taiwan and stationary check

In this paper, the earthquake records are obtained from the seismic archive of the Central Weather Bureau (CWB) in Taiwan. Two kinds of seismic data, labelled and unlabeled, are in the CWB's public file. The labelled ones are those larger than 4.0 on the Richter magnitude scale and influence several cities, and the unlabeled ones are those affect only in the locality. Not until May2000 did the CWB start to record those localized earthquakes.

Yearly earthquake number records as well as stationary check of earthquakes from 1995 to 2017

The stationarities of the time series for the yearly total (labelled plus unlabeled) and labelled earthquakes from 1995 to 2017 are checked. The stationary of variables should be confirmed to avoid the spurious condition if the regression of two time-series is considered [7].

Yearly total number of earthquakes

The stationary of the total number of earthquakes from 1995 to 2017 is checked in this section. The yearly data are shown in Table B1. The augmented Dickey-Fuller method is used for checking the stationary of a time series.

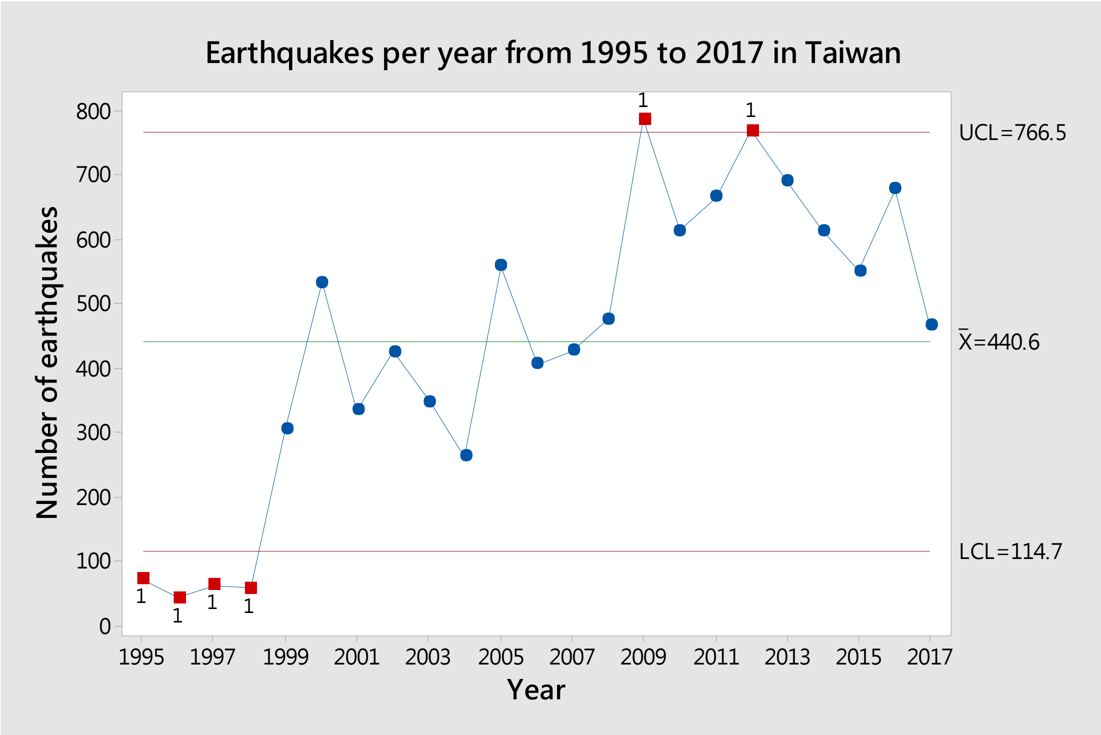

Figure 1: Number of earthquakes per year from 1995 to 2017 in Taiwan

From the figure above, one finds that are an average of 440.6 earthquakes hitting Taiwan every year from 1995 to 2017 (23 years). From years 1995 to 1998, the number of earthquakes is three standard errors below the mean. The fewer the earthquakes means the more the accumulation of energy, which may trigger a catastrophic 7.3 Richter magnitude scale (M_L) earthquake that killed 2,321 people in 1999 [4].

After scrutinizing the seismic archive of the CWB, the number of total earthquakes (both labelled and unlabeled) from January 1995 to May 2018 is 10,829 (partial data are in Table B2), but that of the labelled ones is only 3,248, which is less than one third of the total earthquakes.

The stationary check of yearly number of earthquakes

The augmented Dickey-Fuller (ADF) unit root test [7] is used to test the stationary of yearly number of earthquakes from 1995 to 2017. The basic hypothesis of the unit root test is shown in Appendix A, which tests a time series without constant and trend. Other various forms, such as with constant and trend can refer to a famous textbook by Hill et al. [7]

The result of the augmented Dickey-Fuller (ADF) test is in Table 1. The null hypothesis that the yearly number of earthquakes is no stationary, which cannot be rejected at 5% level of significance. Expressed in another way, there is insufficient evidence to suggest that the time series of the number of yearly earthquake from 1995 to 2017 is stationary.

Table 1: The critical values and Dickey-Fuller unit root test for yearly total number of earthquakes from 1995 to 2017

$\tau(t)$ Test statistic	1% Critical value	5% Critical value	10% Critical value
-2.088	-3.43	-2.86	-2.57

MacKinnon approximate p-value for $\tau(t)$ = 0.2492

The number of yearly labelled earthquakes from 1995 to 2017

This subsection is used to check whether the time series of the yearly number of earthquakes is stationary or not.

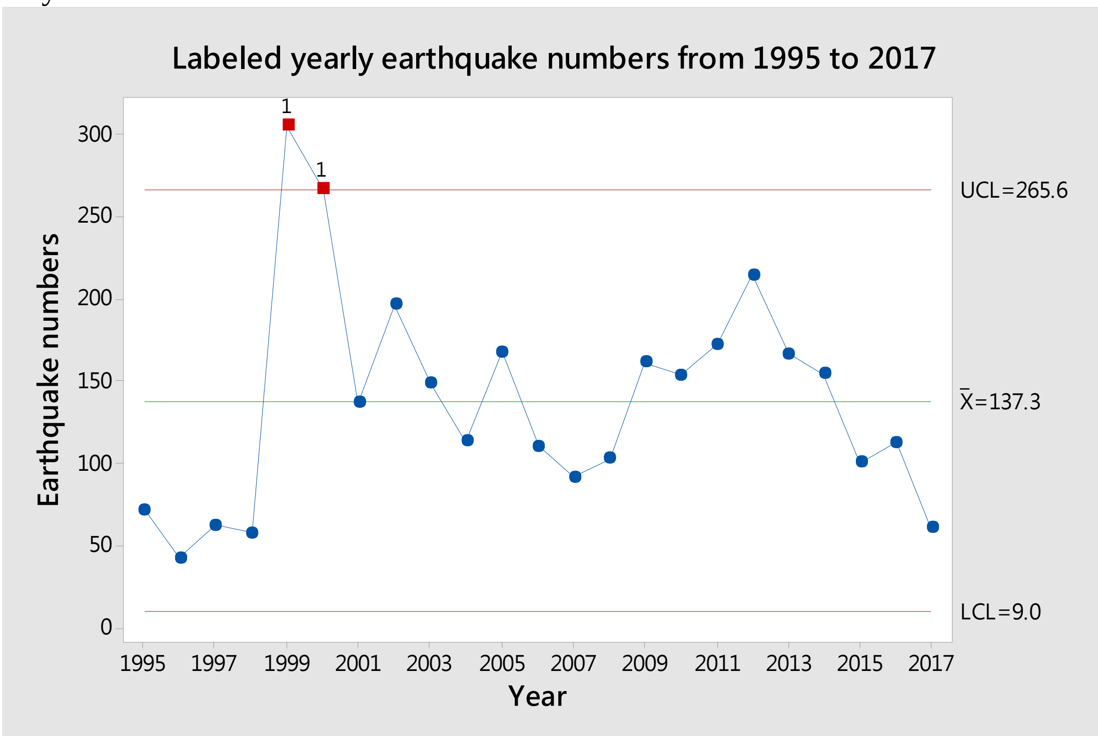

Figure 2: Yearly number of labelled earthquakes from 1995 to 2017 in Taiwan

From figure 2, an average of 137.3 labelled earthquakes occurred in Taiwan every year, and that number is less than one-third of the mean value of total earthquakes in figure 1. From figure 2, there are two years, 1999 and 2000, when the labelled earthquakes in Taiwan are three standard errors above the mean. Again, the Richter scale 7.3 921 earthquake and its aftershocks draw up the number of earthquakes in these two years.

From figures 1 and 2, one finds that the patterns of total and yearly number of labelled earthquakes are very different. In figure 1, it seems the number of earthquakes has a trend upward; however, in figure 2, the number of labelled earthquakes looks quite stationary.

Stationary check of labelled yearly number of earthquakes

As mentioned above, two types of earthquake data are stored in CWB's archive, labelled and unlabeled. The time series for the total earthquakes from 1995 to 2017 has been checked by the unit root test and proved to be no stationary. Whether the time series for the yearly labelled earthquakes is stationary or not is the major concern in this subsection. The result of the augmented Dickey-Fuller test is shown in the Table 2, and it is proved to be stationary, but the *p-value*s close to 5% significance level. Therefore, further tests by other methods are recommended.

Table 2: The critical values and Dickey-Fuller unit root test for yearly labeled earthquake numbers from 1995 to 2017

$\tau(t)$ Test statistic	1% Critical value	5% Critical value	10% Critical value
-2.876	-3.43	-2.86	-2.57
MacKinnon approximate *p*-value for $\tau(t)$ = 0.0482			

The hypothesis H_0: no stationary is rejected. In other words, the yearly number of labelled earthquake from 1995 to 2017 is stationary. A contradictory result is obtained by the Views, which judges the number of yearly labelled earthquake is no stationary. Other methods, such as Dickey-Fuller generalized least squares (DF-GLS), Phillips-Peron (PP), and Ng-Peron (NP) show different hypothesis conclusions. The reason might be that records of only 23 years are collected and it is too few for a correct judgement. Usually at least 50 records are suggested for the time series analysis [6,7].

Stationary check of the monthly number of earthquakes

There are 281 months from January 1995 to May 2018. In this section, the stationarities of the monthly number of total and labelled earthquakes are checked. The number of earthquakes in each month is partly shown in Table B2 due to the length of the list.

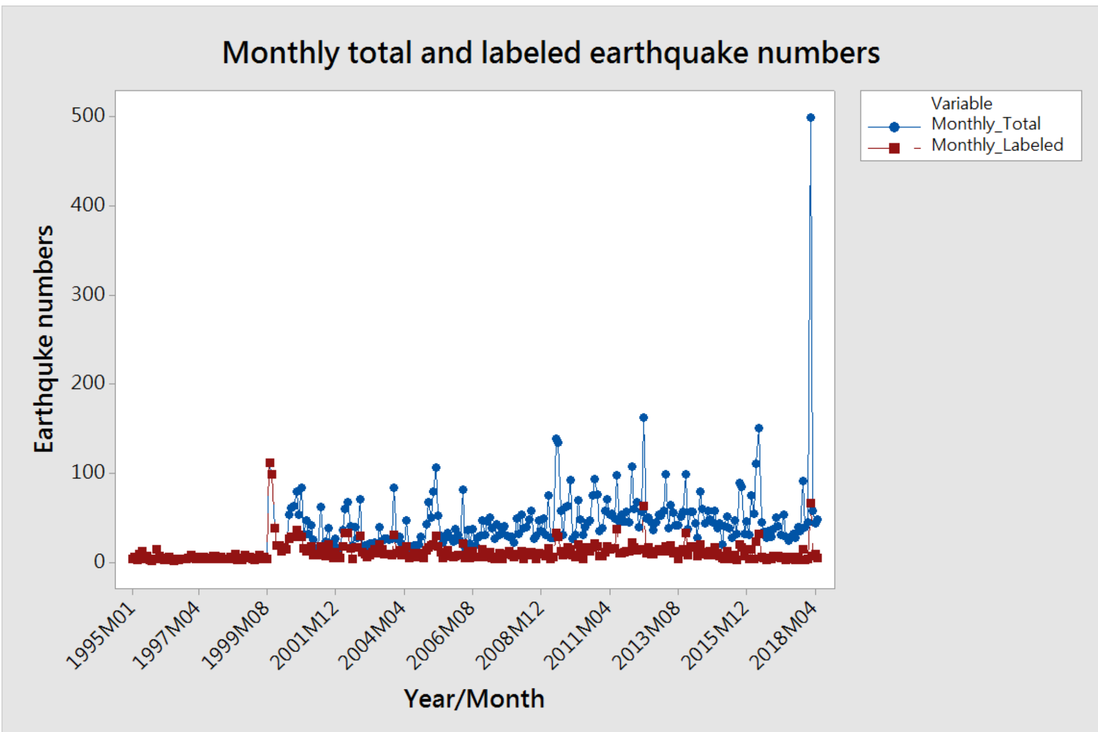

Figure 3: Monthly total and labelled number of earthquakes from January 1995 to May 2018

The total and labelled number of earthquakes per month is plotted in the above figure. Before May 2000, two time series are consistent, but after that time point, two time series separate from each other. This is because the CWB added local small scale seismic records after May 2000, making the two time series different. One extreme point can be found in the upper right corner of

figure 3, which is February 2018. Totally 500 earthquakes were recorded in that month, that records the highest point from January 1995 to May 2018 (281 months).

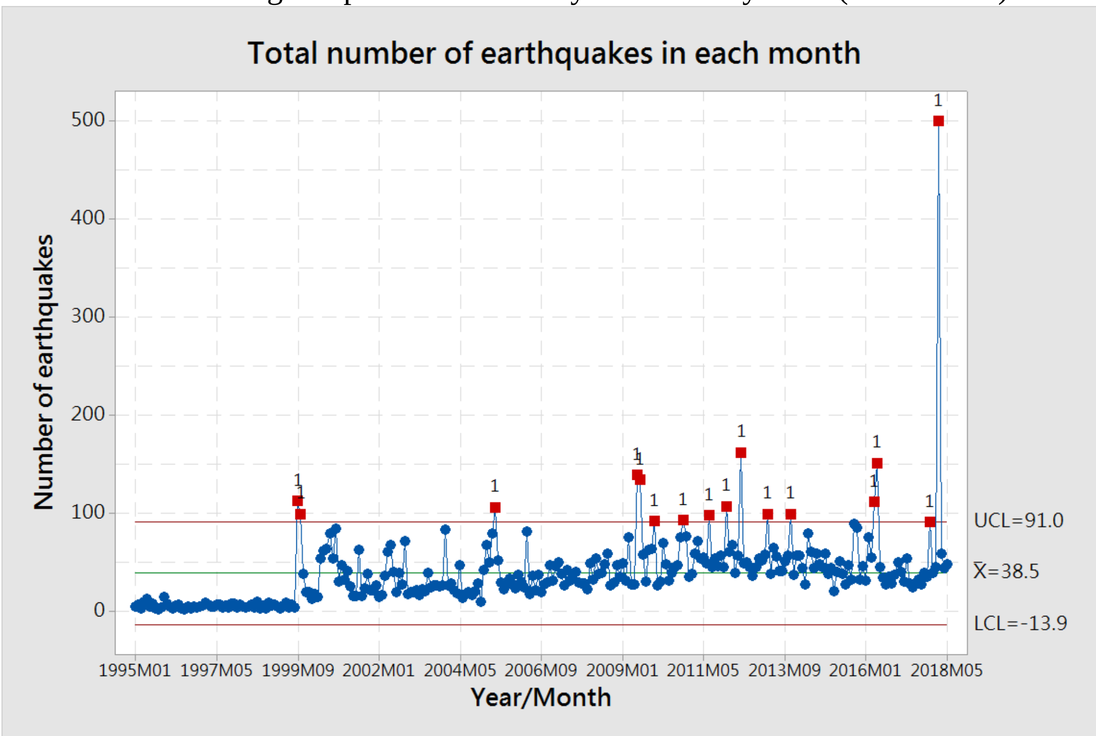

Figure 4: Total number of earthquakes per month from January 1995 to May 2018

The total number of earthquakes per month from January 1995 to May 2018 is plotted in the above figure. Sixteen months are above three standard errors above the mean. The mean value of earthquakes per month is 38.5 times.

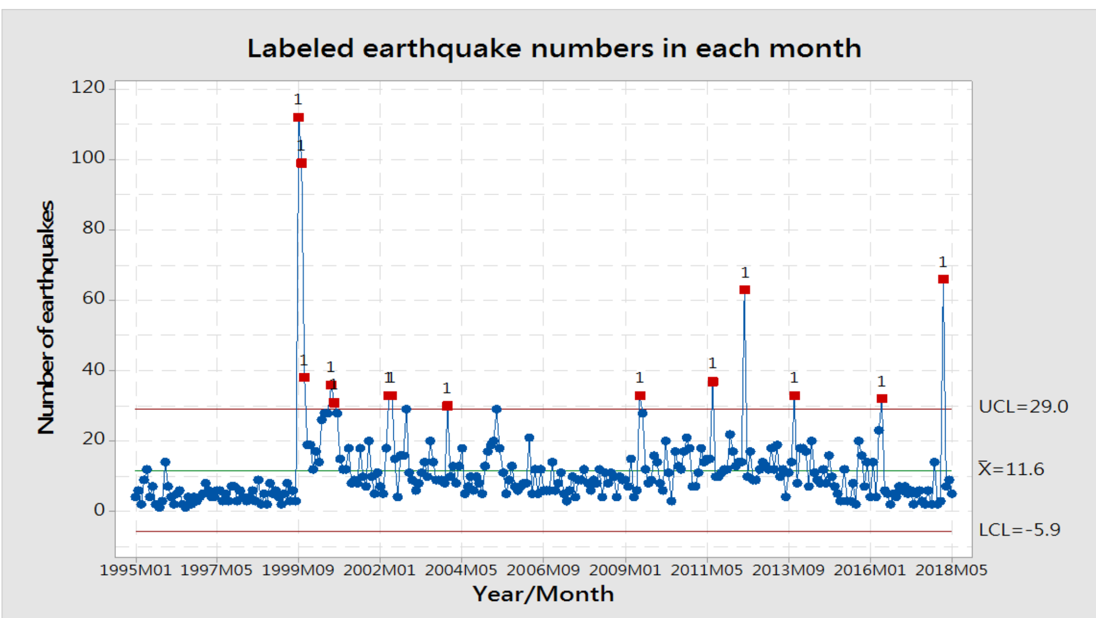

Figure 5: Labelled earthquake numbers per month from January 1995 to May 2018

The labelled number of earthquakes per month is plotted in the above figure, and there are thirteen months above three standards above the mean. The mean value is 11.6 times of labelled earthquakes occurring in a month.

Stationary check of total number of earthquakes per month

The augmented Dickey-Fuller (ADF) unit root test is used to test the stationary of the total number of earthquakes time series. The unit root test result of the total earthquake time series is shown in Table 3.

Table 3: The augmented Dickey-Fuller (ADF) test of the total number of earthquakes

$\tau(t)$ Test statistic	1% Critical value	5% Critical value	10% Critical value
-12.21	-3.43	-2.86	-2.57
MacKinnon approximate *p*-value for $\tau(t) =$ 0.0000			

The hypothesis test H_0: no stationary is rejected at 5% significance level, so that the time series of the monthly total number of earthquakes is stationary. The result obtained from the unit root test can be expressed as:

$$\Delta \widehat{Monthly\_Total_t} = 26.981 - 0.697 Monthly\_Total_{t-1} \quad (1)$$
$$\tau(t) \quad (8.61) \quad (-12.21)$$

Where $Monthly\_Total_t$ is the total number of earthquakes in a month at time *t*, and Δ is time difference.

Stationary check of the labelled number of earthquakes per month

The augmented Dickey-Fuller (ADF) unit root test is used to test the stationary of the labelled number of earthquakes time series. The uni t root test result of the labelled earthquake time series is shown in Table 4.

Table 4: The augmented Dickey-Fuller (ADF) test of the labelled number of earthquakes

$\tau(t)$ Test statistic	1% Critical value	5% Critical value	10% Critical value
-10.45	-3.43	-2.86	-2.57
MacKinnon approximate *p*-value for $\tau(t) =$ 0.0000			

The hypothesis test H_0: no stationary is rejected at 5% significance level, so that the time series of the monthly labelled number of earthquakes is stationary. The result obtained from the unit root test can be expressed as:

$$\Delta \widehat{Monthly\_Labeled_t} = 6.535 - 0.564 Monthly\_Labeled_{t-1} \quad (2)$$
$$\tau(t) \quad (7.35) \quad (-10.45)$$

Where $Monthly\_Labeled_t$ is the monthly labelled earthquakes at time *t*an Δ is time difference.

The stationary check of the energy generated by the earthquake in each month

The energy generated from each earthquake is accumulated monthly. Since the value is huge, to make analysis easier, the energy released of each earthquake is "normalized" by the energy produced by the Little Boy atomic bomb. The Little Boy generated 63TJ (6.3E+20 ergs) of energy when dropped on Hiroshima, Japan [5].

Stationary check of the energy released from monthly total number of earthquakes

The energy released from each earthquake is huge. In this study, the energy released is "normalized" by the "Little Boy" atomic bomb which was dropped on Hiroshima, Japan, with energy issued 63TJ [5]. The energy generated by each earthquake is calculated based on the equation given by Gutenberg and Richter [2]:

$$Energy = 10^{11.8+1.5M_s} \qquad (3)$$

Where *Energy* is expressed in ergs, and M_s is the surface wave magnitude [2,3].

The stationary of energy released by the total earthquakes (labelled plus unlabeled) in each month is checked based on the data given by the CWB and summarized in Table B2. The augmented Dickey-Fuller unit root test is used for checking the stationary of the energy time-series, and the result is expressed in Table 5.

Table 5: The augmented Dickey-Fuller (ADF) test of the energy released from the monthly total earthquakes

$\tau(t)$ Test statistic	1% Critical value	5% Critical value	10% Critical value
-16.59	-3.43	-2.86	-2.57
MacKinnon approximate *p*-value for $\tau(t)$ = 0.0000			

$$\Delta \widehat{Bombs\_Total}_t = 2.869 - 0.995 Bombs\_Total_{t-1} \quad (4)$$

$$\tau(t) \qquad (4.04) \quad (-16.59)$$

Where $Bonbs\_Total_t$ is the energy equivalent to atomic bombs by the total earthquakes in a month at time *t*, and Δ is time difference.

The hypothesis test shows the H_0: no stationary is rejected at 5% significance level. In other words, time-series of the energy released by the monthly total earthquakes is stationary.

Stationary check of the energy released from monthly labelled earthquakes

The energy released by the labelled earthquakes per month are accumulated and tested by the ADF unit root method. The result is shown in Table 6.

Table 6: The augmented Dickey-Fuller (ADF) test of the energy released from the monthly labelled earthquakes

$\tau(t)$ Test statistic	1% Critical value	5% Critical value	10% Critical value
-16.60	-3.43	-2.86	-2.57
MacKinnon approximate *p*-value for $\tau(t)$ = 0.0000			

$$\Delta \widehat{Bombs\_Labeled}_t = 2.736 - 0.995 Bombs\_Labeled_{t-1} \quad (5)$$
$$\tau(t) \qquad (3.87) \quad (-16.60)$$

Where *Bombs_labeled*$_t$is the energy equivalent atomic bombs issued by the labelled earthquakes in a month at time *t*an Δ is time difference.
The hypothesis test shows the H_0: no stationary is rejected at 5% significance level. In other words, time-series of the energy released by the monthly labelled earthquakes is stationary.

Number of earthquakes in each city/county in Taiwan

The bar and pie charts are used to express the number and percentage ratio of total and labelled earthquakes in 20 municipal cities and counties in Taiwan.

Total (labelled plus unlabeled) earthquake numbers in each city/county

A bar chart in decreasing order is plotted as follows to show the total number of earthquakes occurring in the whole 20 municipal cities and counties in Taiwan.

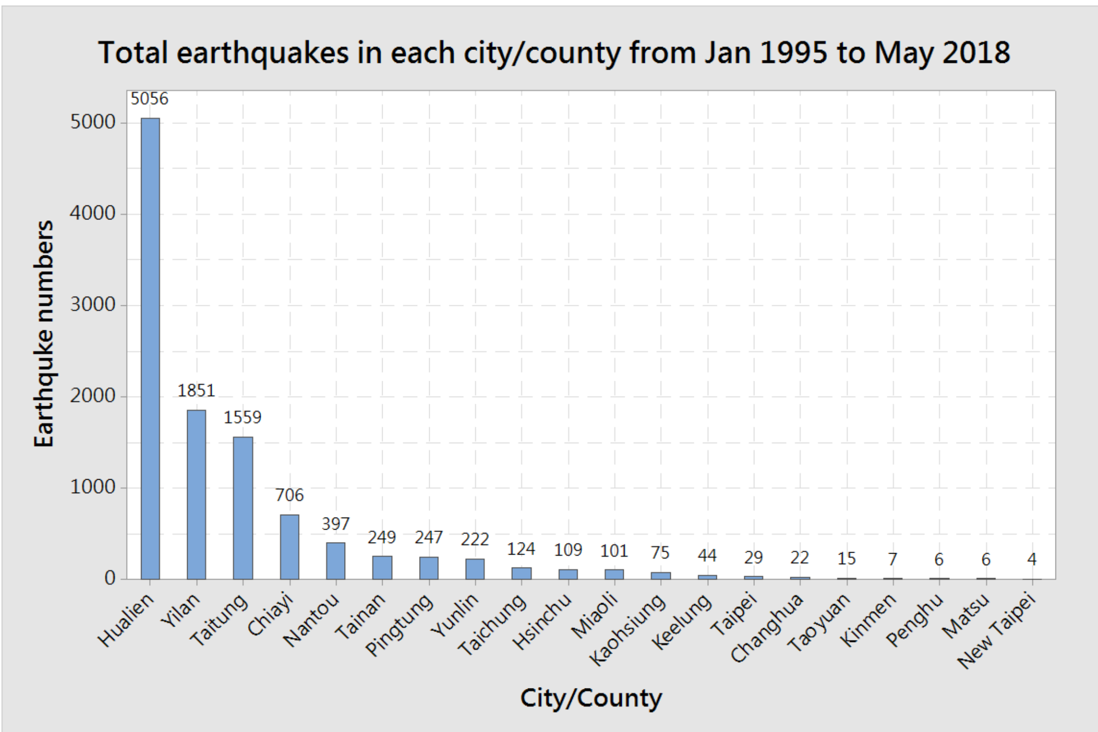

Figure 6: Total earthquake numbers in each city/county from January 1995 to May 2018

From January 1995 to May 2018, a total of 5,056 earthquakes occurred in Hyaline, followed by Milan (1,851) and Tatung (1,559). The percentage ratio of earthquakes in each city and county to the total number of earthquakes is shown in the following pie chart.

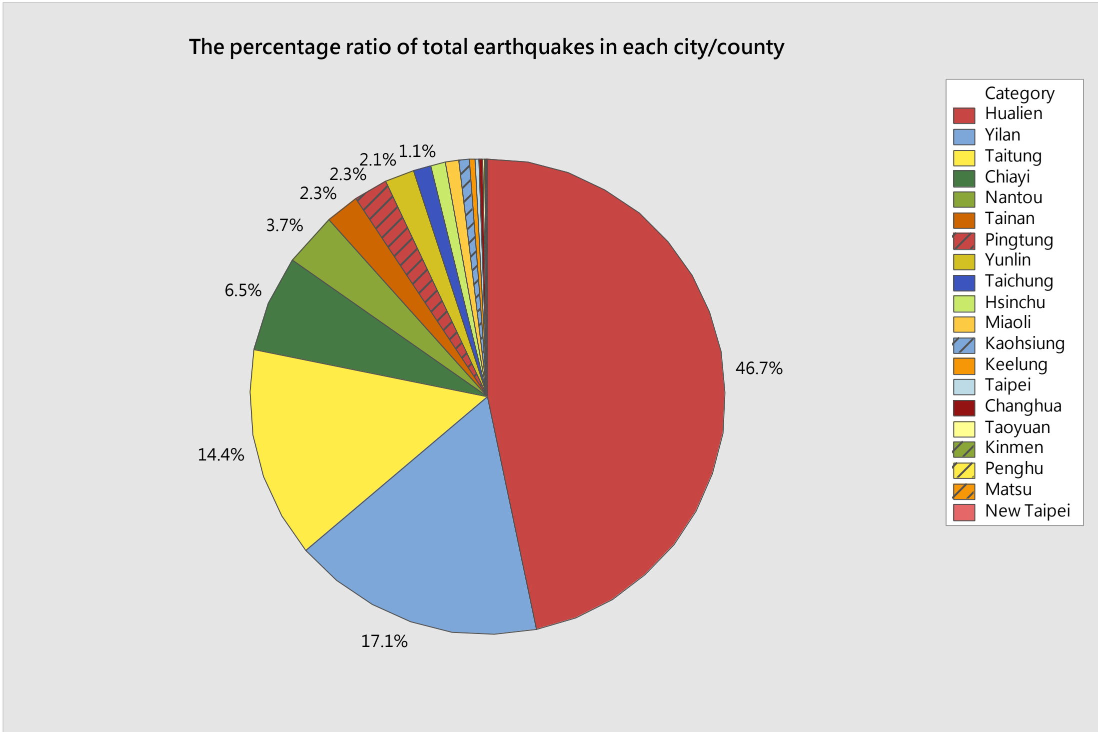

Figure 7: The percentage ratio of total earthquakes in each city and county

From the above figure, obviously Hyaline is the area with the most frequent earthquake, and Milan and Tatung ranked as second and third. From January 1995 to May 2018, there are 10,829 earthquakes occurring in Taiwan, and 46.7% of them were recorded in Hyaline.

Labelled earthquake numbers in each city/county

A bar chart in decreasing order is plotted to show the number of earthquakes occurring in the past 281 months in each city and county in Taiwan.

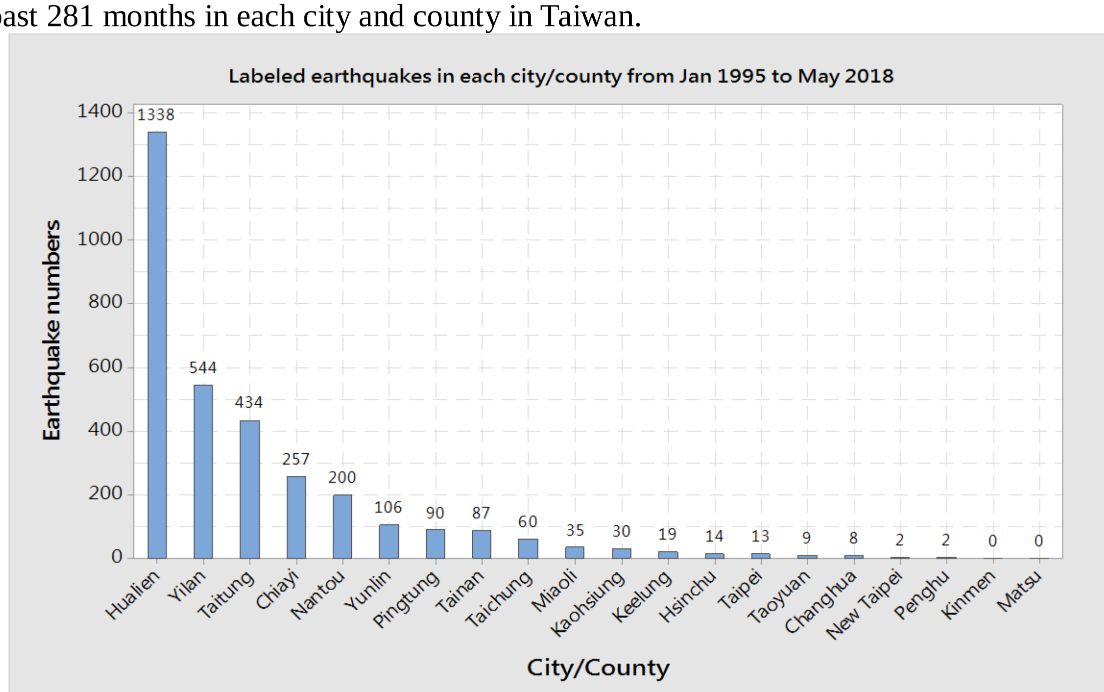

Figure 8: Labelled earthquakes in each city/county in Taiwan from January 1995 to May 2018

The most frequent labelled earthquakes obviously occurred in Hyaline. Totally 5,056 earthquakes occurred in Hyaline, but only 1,338 are labelled. It also means those 3,718 (5,056-1,338) earthquakes are localized with smaller impact on the Hyaline area. However, the energy contribution of these small-scaled earthquakes cannot be neglected. From Table B3, one finds that the energy difference between the two is equivalent to 8.3 atomic bombs difference if these 3,718 small-scaled earthquakes were not taken into consideration.

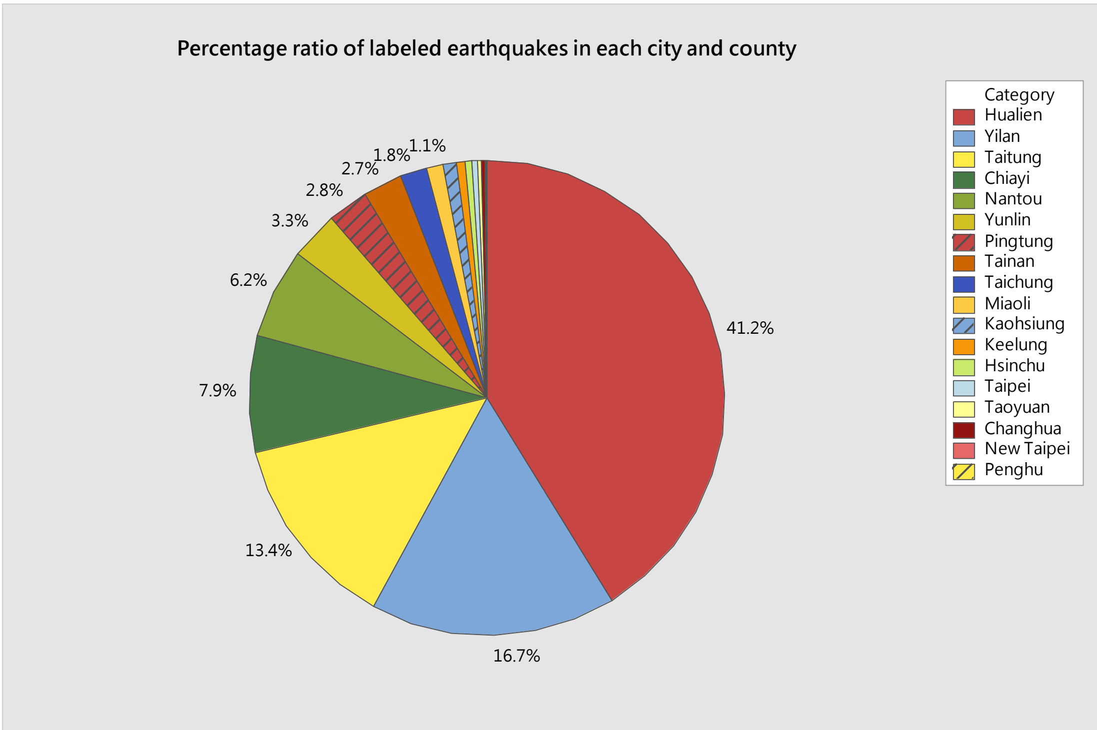

Figure 9: Percentage ratio of labelled earthquakes in each city and county from January 1995 to May 2018

From January 1995 to May 2018, there are 3,248 earthquakes occurring in Taiwan, and 41.2% of them are recorded in Hyaline.

Energy distribution of each city and county in Taiwan

The energy released of earthquakes in each city and county is recorded in Table B3. Since their values are usually huge, in this study, the author “normalized” them with the energy generated by the atomic bomb dropped in Hiroshima, Japan, which released 63TJ of energy [5]. In the past 281 months, the total and labelled earthquakes occurring in each city and county are plotted in bar and pie charts.

Energy generated by the total earthquakes in each city and county

In the past 281 months, the earthquakes released huge amount of energy. It is more convenient to “normalize” it. In this study, the author accumulated energy issued from each earthquake in each city and county, and “normalized” it with the energy generated by the Hiroshima atomic bomb, which produced 63TJ [5]. The bar and pie charts are used to express equivalent number of atomic bombs and ratio of energy respectively.

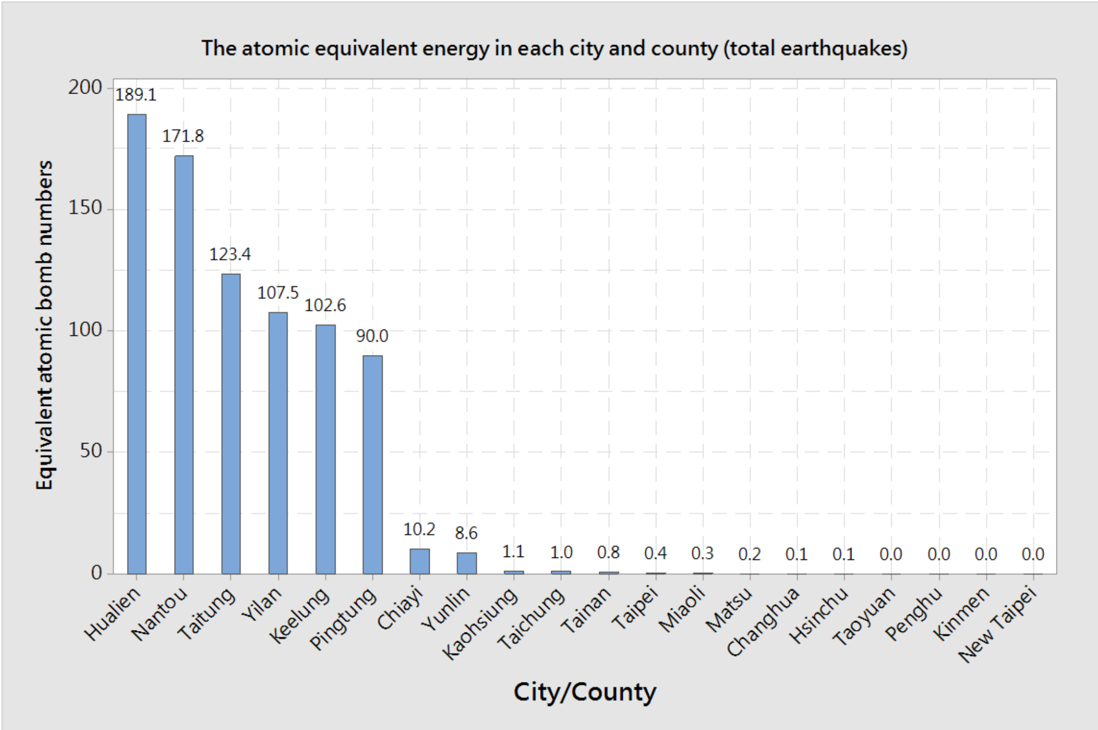

Figure 10: Atomic bomb equivalent energy of total earthquakes in each city/county

From the above graph, one finds that the total earthquakes in Hyaline accumulated 189.1 atomic bombs, followed by Manitou (171.8) and Tatung (124.4). Because the energy issued from each earthquake is calculated with $11.8+1.5M_s$ power of ten, the magnitude 7.3 earthquake on September 21, 1999 has a significant contribution to the energy in Manitou.

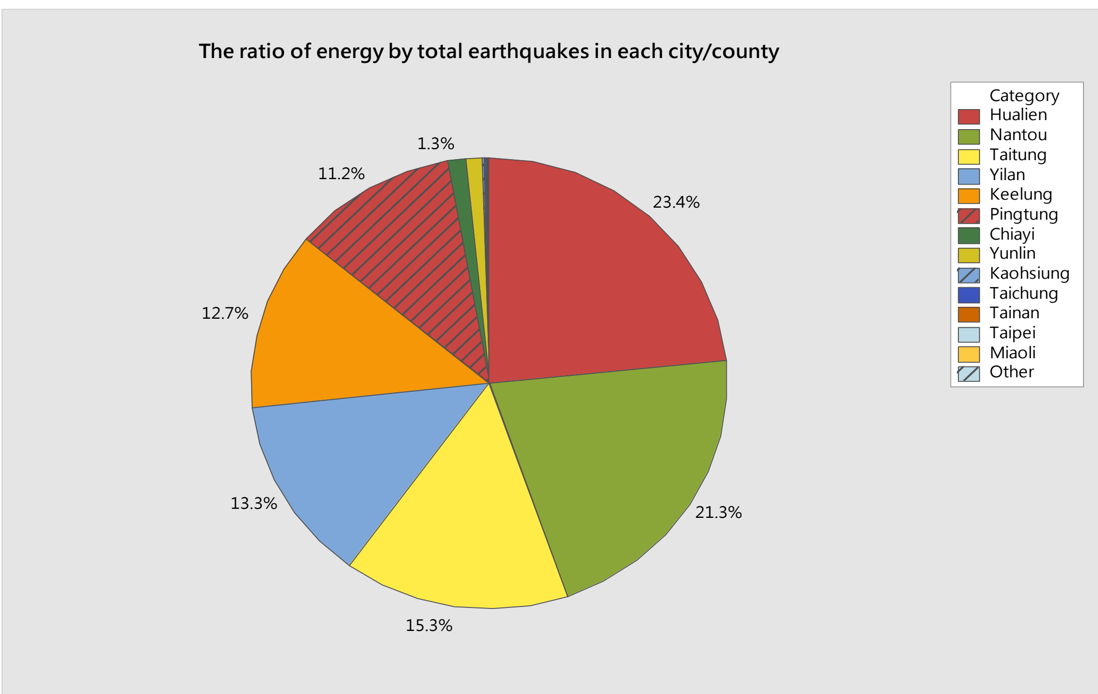

Figure 11: The energy released by the total number of earthquakes of each city and county

From the above pie chart, one finds the energy issued from total earthquakes in Hyaline (23.4%), Manitou (21.3%), Tatung (15.3%), and Milan (13.3%). These four areas counted for 73.3% of the total earthquakes energy in Taiwan.

Energy generated by the labelled earthquakes in each city and county

The bar chart is used to show the number of atomic bombs equivalent energy released in each city and county in the past 281 months. There data are shown in Table B3. In Tatung, the atomic bomb numbers between total and labelled earthquakes differs 19.44 (123.38-103.94). It means in Tatung, the small scaled local earthquakes also contribute tremendously. As for the ratio of energy in Tatung also shows the largest gap between total and labelled energy.

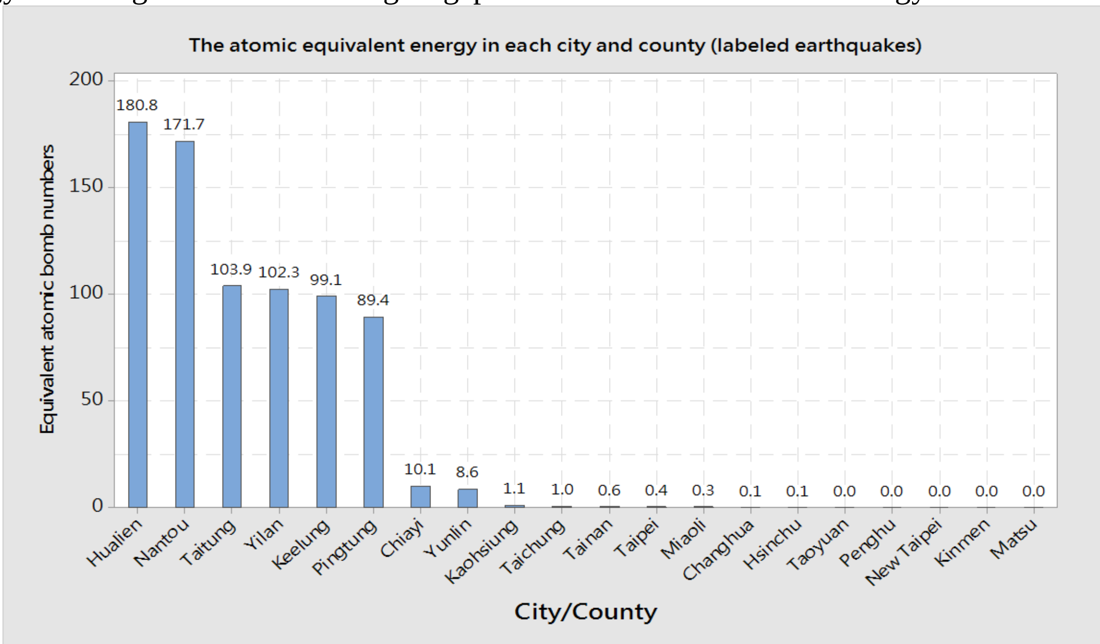

Figure 12: Atomic bomb equivalent energy of labelled earthquakes in each city/county

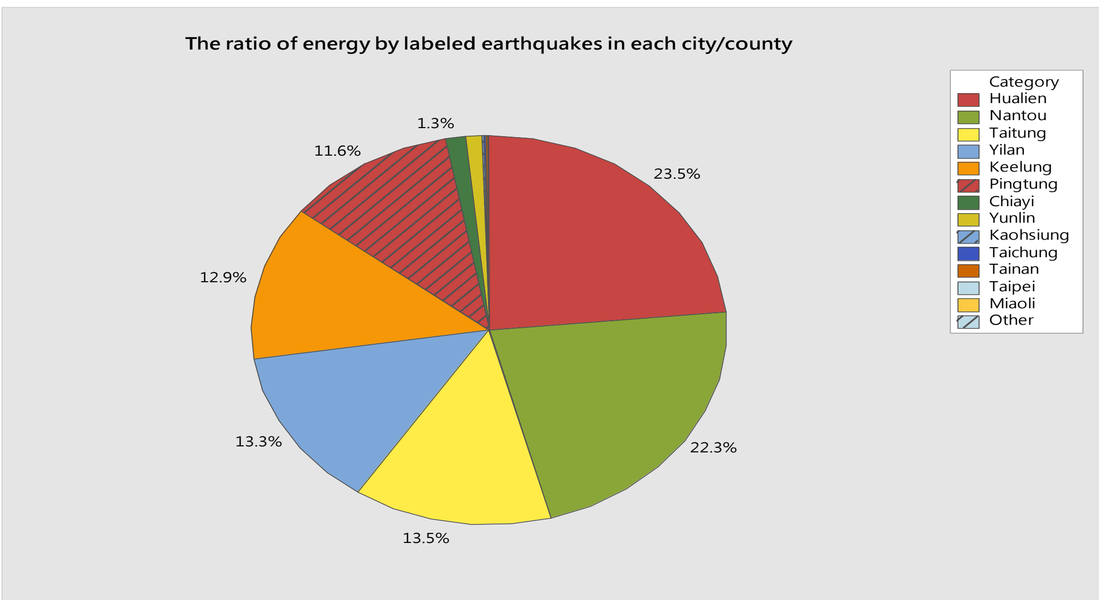

Figure 13: The energy released by the number of labelled earthquakes of each city and county

From the above pie chart, one finds the energy issued from total earthquakes in Hyaline (23.5%), Manitou (22.3%), Tatung (13.5%), and Milan (13.3%). These four areas counted for 72.6% of all the labelled earthquakes energy in Taiwan.

Regression analysis of the number of atomic bombs with respect to the number of earthquakes

This section uses the regression method to connect the atomic bomb and earthquake numbers together. Once the earthquake number is known, substitute it into the regression equation, then equivalent atomic bomb numbers can be estimated. The atomic bomb numbers can be transferred to any unit of energy such as ergs and joules.

Relationship between monthly atomic bomb numbers and monthly total number of earthquakes

The monthly total earthquakes and atomic bomb numbers from January 1995 to May 2018 has been plotted in figure 3.

Using two-step regression algorithm with model without constant term, the regression between atomic bomb numbers and total earthquake numbers per month is as follows:

$$Atomic\ Bomb = 0.0599 Monthly\_Total\_Earthquakes,\ \ R^2_{(adj)} = 7.39\% \quad ..(6)$$

There is a positive relationship between monthly earthquake numbers with respect to energy released in terms of atomic bombs, but the coefficient is quite small. Where $R^2_{(adj)}=7.39\%$, which means the above equation only has very limited explanation of the relationship between atomic bomb numbers per month and total monthly earthquakes (only up to 7.39%).

Relationship between monthly atomic bomb numbers and monthly number of labelled earthquakes

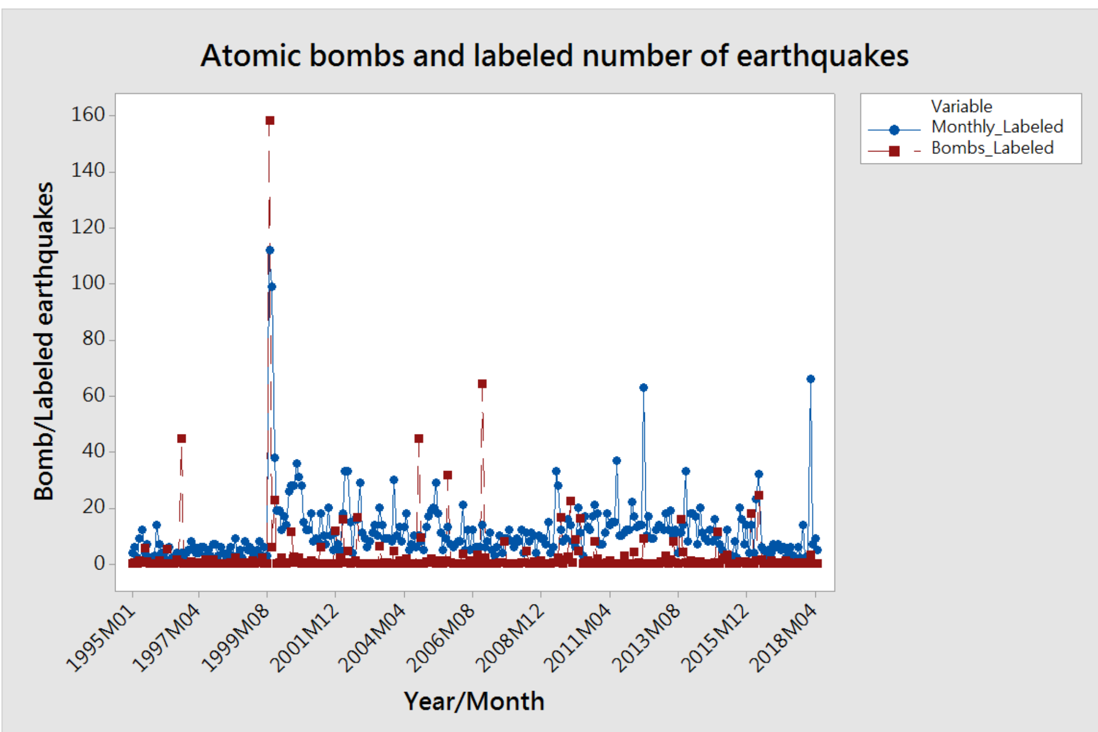

Figure 14: Monthly labelled earthquake numbers and monthly atomic bomb numbers from

January 1995 to May 2018

Atomic Bombs = 0.3638Monthly_Labeled_Earthquakes, $R^2_{(adj)}$ *= 25.57%*........(7)

There is a positive relationship between monthly earthquake numbers with respect to energy released in terms of atomic bombs. Where $R^2_{(adj)}$*=25.57%,* which means the above equation can explain the relationship between atomic bomb numbers per month and monthly labelled earthquakes up to 25.57%.

Conclusions

After analyzing the time series of yearly and monthly number of earthquakes and their energy generation, the following conclusions can be obtained:

The time series of the yearly total number of earthquakes is no stationary; however, the time series of yearly labelled one is inconclusive by different unit root tests algorithm. More than 50 data is recommended.

The monthly total number of earthquakes is a stationary time series. The number of monthly labelled earthquakes is also stationary.

Bothe the time series of the energy released by the total and labelled monthly earthquakes are stationary.

The regression equation between energy and total number of earthquakes can be expressed as:

Atomic Bomb = 0.0599 Monthly_Total_Earthquakes, $R^2_{(adj)}$ *= 7.39%*

It means a positive relationship between monthly total number of earthquakes and energy released in terms of atomic bombs.

The regression equation between energy and labeled number of earthquakes can be expressed as:

Atomic Bombs = 0.3638 Monthly_Labeled_Earthquakes, $R^2_{(adj)}$ *= 25.57%*

It means there is a positive relationship between monthly total number of earthquakes and energy released in terms of atomic bombs. The percentage of explanation of the relationship is 25.57%.

Hyaline is the area with highest frequent of total and labelled earthquakes. For the energy generated by the total earthquakes, Hyaline shares23.4%, and for the energy issued by the labelled earthquakes, Hyaline occupies 23.5%.There is 46.7% number of total earthquakes occurred in Hyaline, and 41.2% of number of labelled earthquakes were recorded in that area.

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Appendices

Appendix A: augmented Dickey-Fuller (ADF) Test [7]

$$y_t = \rho y_{t-1} + \nu_t \qquad \text{(A1)}$$

Where y_t is time series of *y* at time *t*. subtracting y_{t-1} from both sides of (A1)

$$y_t - y_{t-1} = \rho y_{t-1} - y_{t-1} + \nu_t$$
$$\Delta y_t = (\rho - 1) y_{t-1} + \nu_t = \gamma y_{t-1} + \nu_t$$
$$H_0 : \rho = 1 \equiv H_0 : \gamma = 0$$
$$H_1 : \rho < 1 \equiv H_1 : \gamma < 0$$

In other words, *H0: no stationary* and if it is rejected, *H1: stationary*
The extended test equation is

$$\Delta y_t = \alpha + \gamma y_{t-1} + \sum_{s=1}^{m} a_s \Delta y_{t-s} + \nu_t \qquad \text{(A2)}$$

Where α, γ, a_s are coefficients to be determined, and ν_t are residuals. Equation (A2) and its variants are referred to augmented Dickey-Fuller tests.

Appendix B: Earthquake numbers

Table B1 contains total (labelled plus unlabeled) and labelled number of earthquakes. The yearly data are collected from 1995 to 2017, and the number of earthquakes fit into each city and county are assembled from January 1995 to May 2018.

Table B1: Earthquake numbers expressed in years and fit into each city

Year	Labeled Earthquakes	Total Earthquakes	City/ County	Labeled Earthquakes	Total Earthquakes	Ratio of Labeled Earthquakes in Each City/County (%)	Ratio of Total Earthquakes in Each City/County (%)
1995	71	71	Yilan	544	1851	16.7	17.1
1996	42	42	Hualien	1338	5056	41.2	46.7
199	62	62	Taitung	434	1559	13.4	14.4

7							
1998	57	57	Nantou	200	397	6.2	3.7
1999	305	305	Keelung	19	44	0.6	0.4
2000	266	532	Taipei	13	29	0.4	0.3
2001	136	334	New Taipei	2	4	0.1	0.0
2002	196	425	Taoyuan	9	15	0.3	0.1
2003	148	347	Hsinchu	14	109	0.4	1.0
2004	113	262	Miaoli	35	101	1.1	0.9
2005	167	558	Taichung	60	124	1.8	1.1
2006	110	405	Changhua	8	22	0.2	0.2
2007	91	426	Yunlin	106	222	3.3	2.1
2008	102	476	Chiayi	257	706	7.9	6.5
2009	161	786	Tainan	87	249	2.7	2.3
2010	153	614	Kaohsiung	30	75	0.9	0.7
2011	172	666	Pingtung	90	247	2.8	2.3
2012	214	769	Penghu	2	6	0.1	0.1
2013	166	690	Kinmen	0	7	0.0	0.1
201	154	613	Matsu	0	6	0.0	0.1

4							
2015	100	551					
2016	112	678					
2017	60	465					

Table B2: Monthly earthquake numbers and energy released equivalent to atomic bomb numbers (only partly table)

Year/Month	Monthly_ Total	Monthly_ Labeled	Bombs_ Total	Bombs_ Labeled
1995M01	4	4	0.06	0.06
1995M02	6	6	0.60	0.60
1995M03	2	2	0.27	0.27
1995M04	9	9	1.02	1.02
1995M05	12	12	0.36	0.36
1995M06	4	4	5.77	5.77
1995M07	7	7	0.65	0.65
1995M08	2	2	0.04	0.04
1995M09	1	1	0.01	0.01
1995M10	3	3	0.05	0.05
1995M11	14	14	0.10	0.10
1995M12	7	7	1.02	1.02
1996M01	4	4	0.06	0.06
1996M02	2	2	0.01	0.01
1996M03	5	5	5.27	5.27
1996M04	6	6	0.04	0.03
1996M05	2	2	0.05	0.05

1996M06	1	1	0.02	0.02
1996M07	4	4	1.51	1.50
1996M08	2	2	0.52	0.52
1996M09	4	4	44.93	44.93
1996M10	3	3	0.02	0.02
1996M11	4	4	0.22	0.22
1996M12	5	5	0.07	0.07
2017M01	40	7	0.07	0.04
2017M02	30	5	0.44	0.30
2017M03	53	6	0.10	0.08
2017M04	28	2	1.20	1.01
2017M05	24	5	0.44	0.40
2017M06	27	6	0.19	0.17
2017M07	32	3	0.10	0.01
2017M08	27	2	0.62	0.04
2017M09	39	6	0.66	0.43
2017M10	35	2	0.18	0.00
2017M11	91	14	0.37	0.35
2017M12	39	2	0.24	0.13
2018M01	45	3	0.39	0.36
2018M02	500	66	3.34	3.09
2018M03	58	7	0.89	0.13
2018M04	44	9	0.11	0.04
2018M05	48	5	0.23	0.20
Total	10,829	3,248	807.4	769.7

Table B3: The energy released by total and labelled earthquakes in each city and county

City/County	Total Energy Released (ergs)	Equivalent atomic bomb numbers (Total)	Labeled Energy Released (ergs)	Equivalent atomic bomb numbers (Labeled)	Atomic bomb difference
Yilan	6.78E+22	107.54	6.45E+22	102.31	5.23
Hualien	1.19E+23	189.10	1.14E+23	180.80	8.30
Taitung	7.77E+22	123.38	6.55E+22	103.94	19.44
Nantou	1.08E+23	171.77	1.08E+23	171.69	0.07
Keelung	6.47E+22	102.64	6.24E+22	99.07	3.57
Taipei	2.61E+20	0.41	2.59E+20	0.41	0.00
New Taipei	5.11E+17	0.00	6.33E+16	0.00	0.00
Taoyuan	1.60E+19	0.03	1.54E+19	0.02	0.00
Hsinchu	4.20E+19	0.07	3.70E+19	0.06	0.01
Miaoli	2.13E+20	0.34	1.96E+20	0.31	0.03
Taichung	6.34E+20	1.01	6.14E+20	0.97	0.03
Changhua	7.76E+19	0.12	7.44E+19	0.12	0.01
Yunlin	5.44E+21	8.64	5.44E+21	8.64	0.00
Chiayi	6.44E+21	10.23	6.39E+21	10.14	0.08
Tainan	5.10E+20	0.81	4.08E+20	0.65	0.16
Kaohsiung	7.04E+20	1.12	7.00E+20	1.11	0.01
Pingtung	5.67E+22	90.05	5.64E+22	89.45	0.60
Penghu	8.91E+18	0.01	8.34E+18	0.01	0.00
Kinmen	6.48E+18	0.01	0	0.00	0.01
Matsu	1.01E+20	0.16	0	0.00	0.16
Total	5.09E+23	807.4	4.85E+23	769.7	37.7